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CODE GFACE—GAS LUBRICATED FACE SEALS IN LAMINAR REGIME

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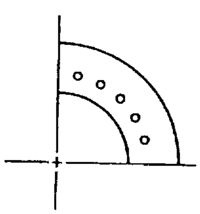
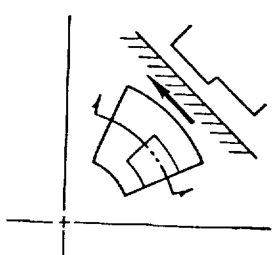
GFACE Capabilities

- **Varying Geometries-Rayleigh-step, Tapered Land, Hydrostatic**
- **Variable Grid**
- **Z, X-X, Y-Y, Degrees of Freedom**
- **Can determine position as a function of load**
- **English or SI Units**

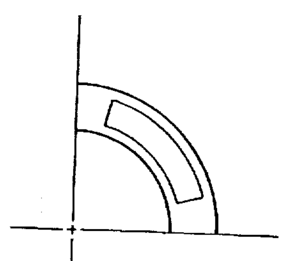
GFACE Configurations



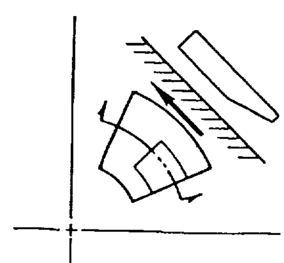
Hydrostatic



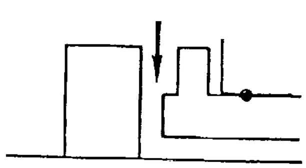
Circumferential Rayleigh Step



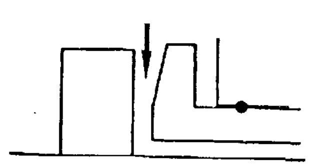
Hydrostatic Recess



Circumferential Tapered Land

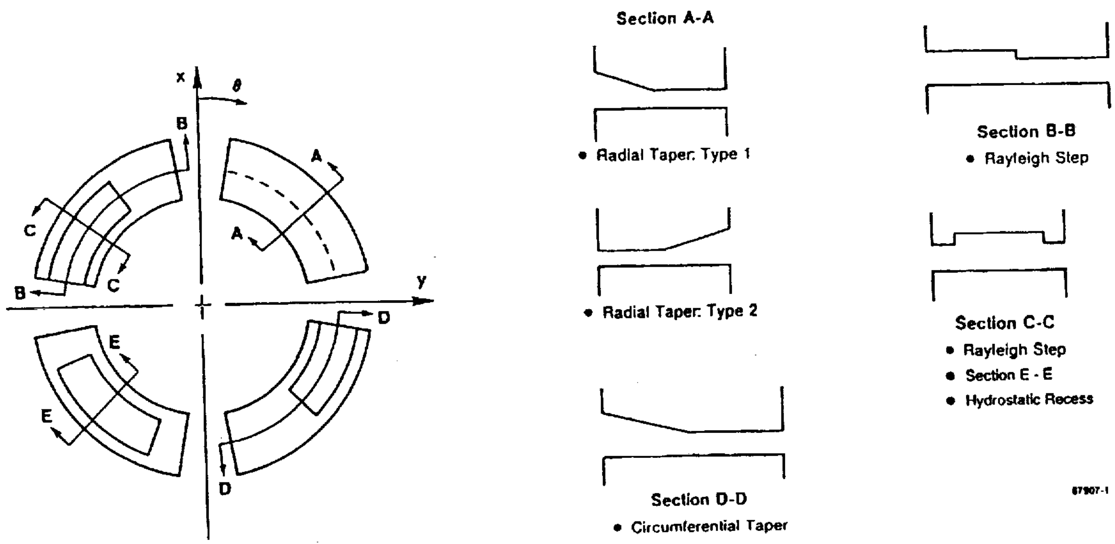


Radial Rayleigh Step



Radial Tapered Land

GFACE Configurations



GFACE Output

- Clearance Distribution
- Pressure Distribution
- Leakage along specified flow paths
- Interface load
- Righting Moments
- Viscous Dissipation
- Frequency dependent stiffness and Damping
- Plotting Routines

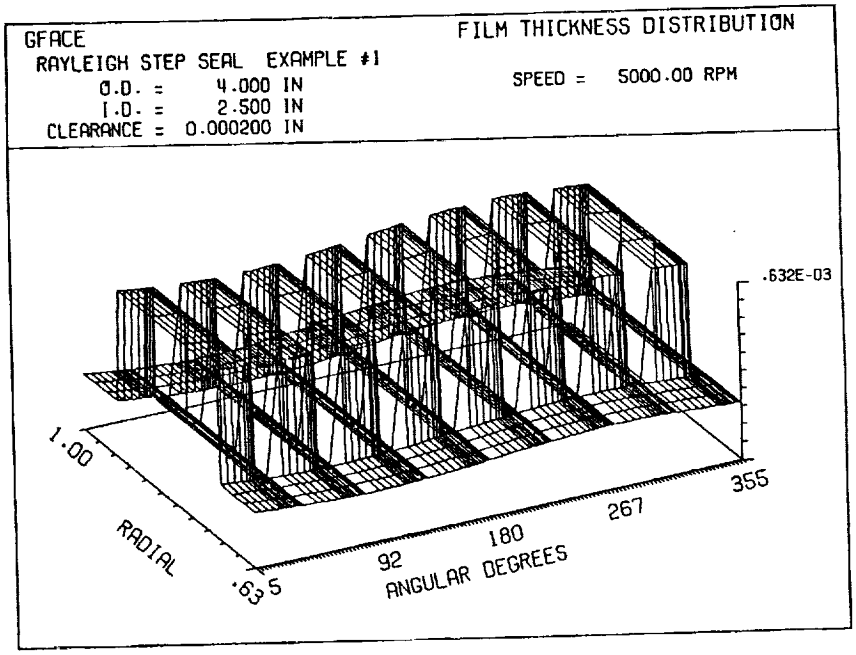
GFACE Examples

- Rayleigh-step seal with Misalignment
- Tapered Land Seal, Option 2
- Hydrostatic Recess
- Hydrostatic Recess, Periodic Pads
- Inherently Compensated Hydrostatic Seal
- Radial Tapered Seal

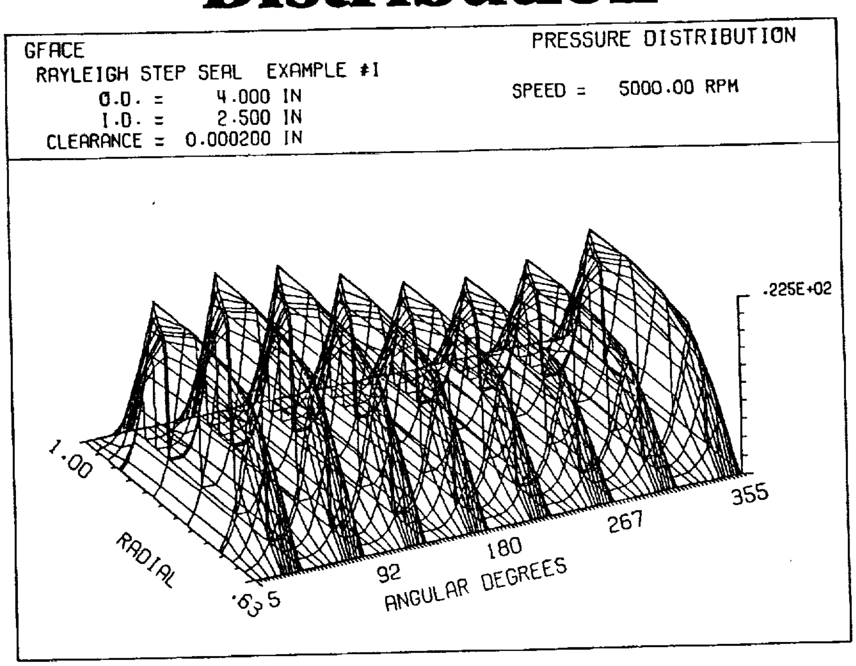
Rayleigh Step Seal Input

Number of pads, NPAD	8
Outer diameter	4.0 inch
Inner diameter	2.5 inch
Angular extent of pad	35 degrees
Starting angle of first pad	5 degrees
Given displacement, find load. OPTION	1
Compute stiffness at synchronous frequency	5000
Apply variable grid	
Clearance	0.0002 inch
Misalignment angle about the X-axis	-0.001 degree
Number of steps in grid	1
Step depth	0.0004 inch
Location of step	
Lower left corner	I=5, J=1
Upper right corner	I=8, J=8
Specific heat ratio	1.4
Gas constant	246,900 in.^{2}/s^2/°R
Absolute temperature	1460°R
Viscosity	5.35 x 10^{-9} lbs-s/in^2
Speed	5000 rpm
Convergence tolerance	0.01
Ambient (reference) pressure	14.7 psi

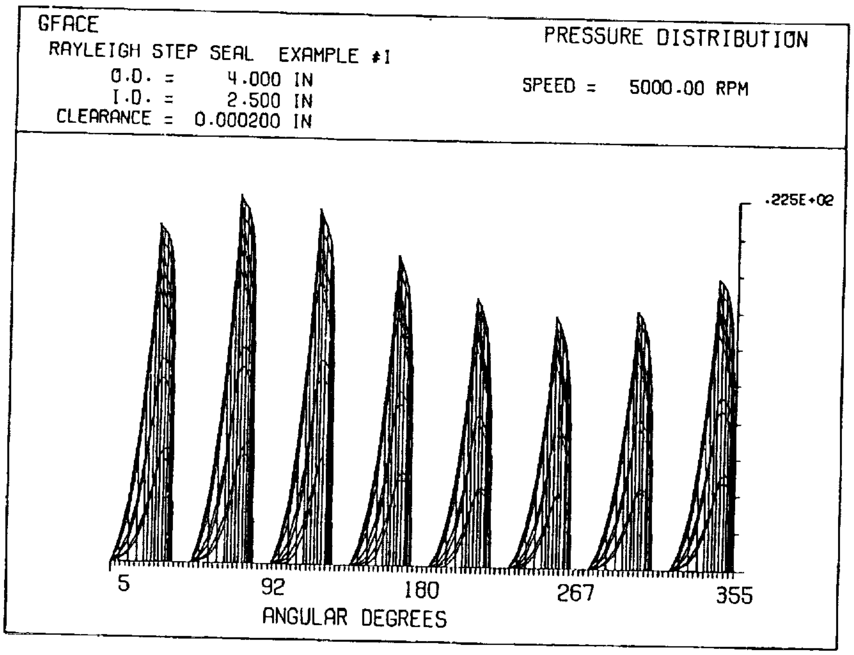
Rayleigh-Step Seal Clearance Distribution



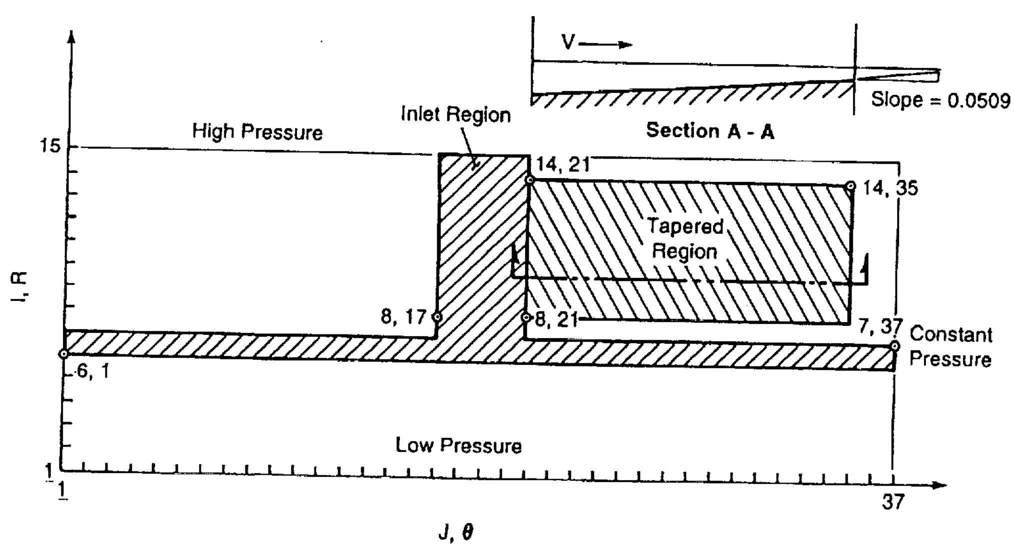
Rayleigh-Step Seal Pressure Distribution



Rayleigh-Step Seal Pressure Distribution



Tapered-Land Seal Grid Geometry



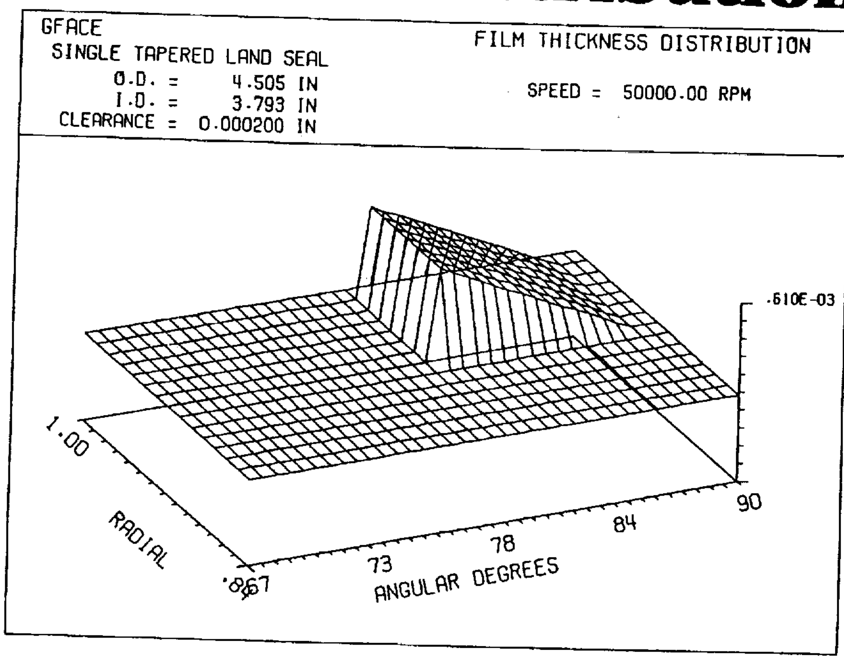
Tapered-Land Seal Input

OPTION	2 Signifies that the load will be supplied and the axial position determined.
LOAD	13 lbs is the load to be balanced
STIFFNESS	0.0001 A non synchronous, frequency independent stiffness is desired.
NPAD	1 One of the 16 pads is modeled, with periodic conditions along the radial boundaries.
OUTER	4.5 = the outer diameter ,in.
INNER	3.793 = the inner diameter, in.
CLEARANCE	= 0.0002 in. = Initial guess at the axial clearance to support the given load.
START	= 67.5 degrees = start angle of pad
PADANGLE	= 22.5 degrees = angular extent of pad
GRIDN	= 37 = number of grid points in the θ direction
GRIDM	= 15 = Number of grid points in the radial direction
CTAPER	= 1 = Number of circumferential tapers in the grid Slope of taper = 0.05209 Lower left corner of taper, I = 8, J=21 Upper right corner of taper, I=14, J=35

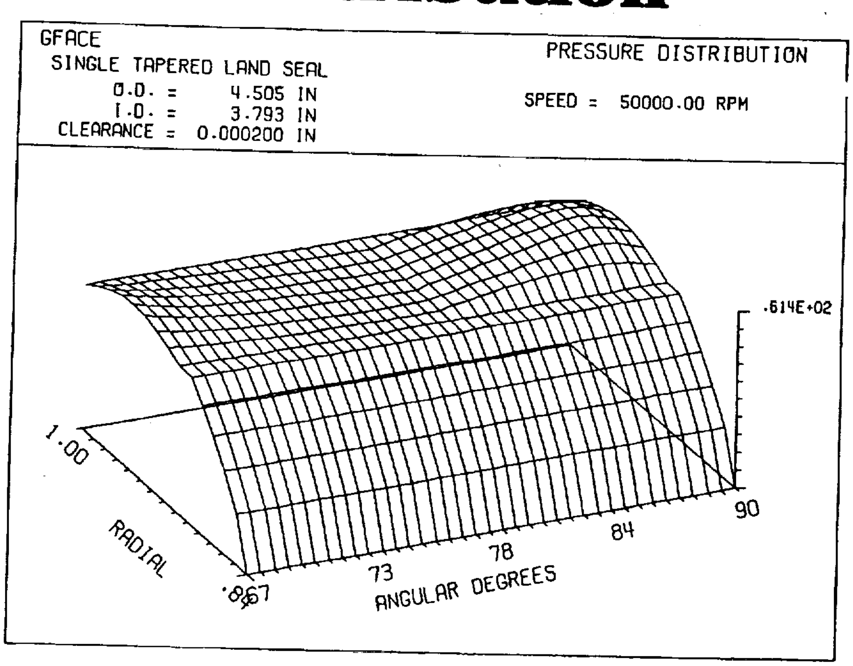
Tapered-Land Seal Input

VISCOSITY	1.75×10^{-9} lb-s/in^2
GASCONST	= gas constant = 423,184 in^2/s^2/^{o}F
JOINED	Periodic boundaries apply
ITERATION	= 15, 15 = maximum iterations for pressure and load convergence
TOLERANCE	.020, .020 = tolerances on pressure and load convergence
SPEED	50,000 rpm
PO	= 14.7 = reference or ambient pressure, psig
PLEFT	= 0. = Pressure on left radial boundary. Since periodic boundary conditions apply PLEFT has no consequence.
PRITE	= 0. = Pressure on right radial boundary. Since periodic boundary conditions apply PRITE has no consequence.
PTOP	= 50 psig = pressure boundary at outer radius, I=M
PBOT	= 0 psig = pressure boundary at inner radius, I=1

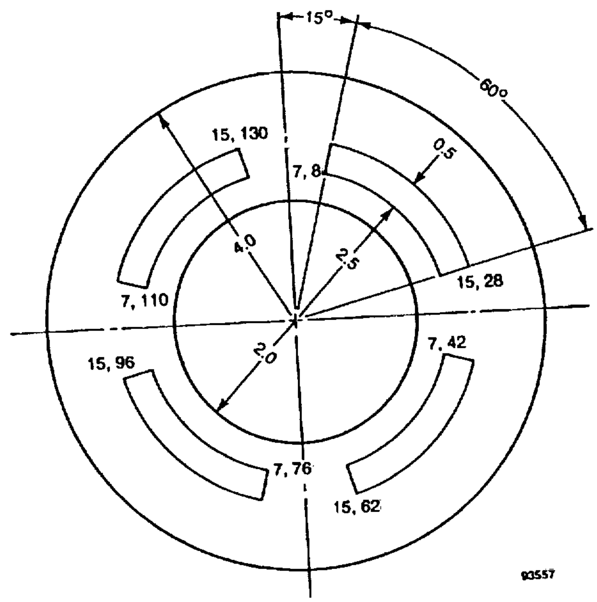
Tapered-Land Seal Clearance Distribution



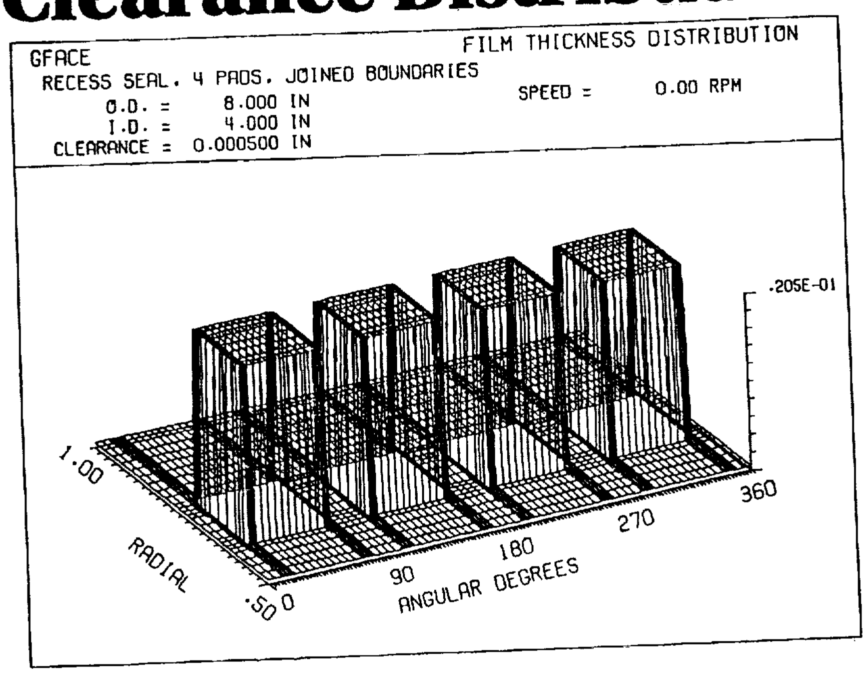
Tapered-Land Seal Pressure Distribution



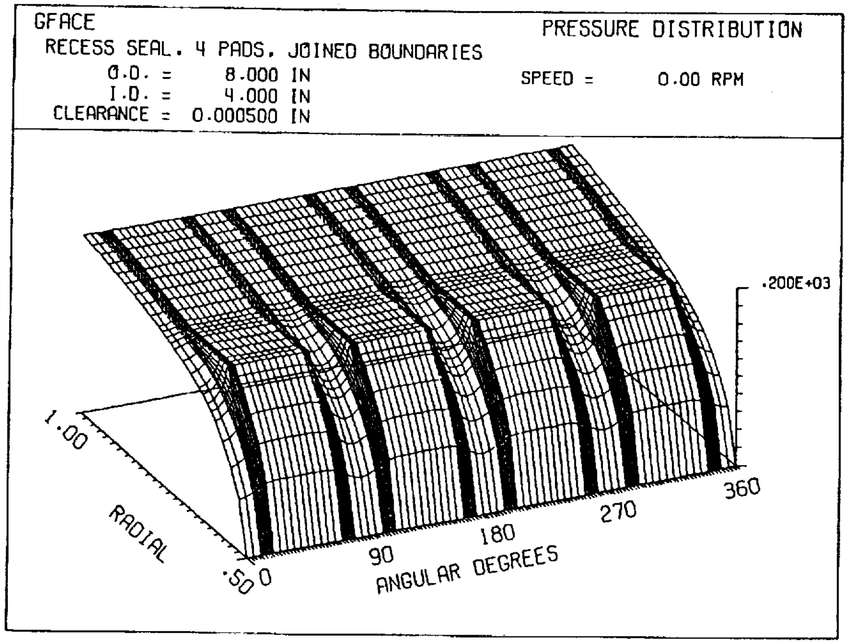
Hydrostatic Recess Seal



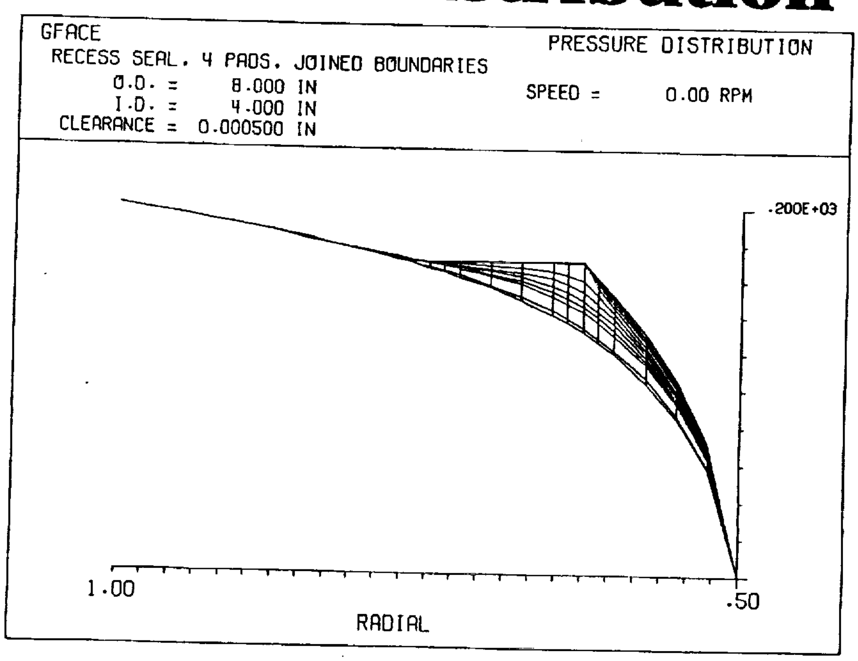
Hydrostatic Recess Seal Clearance Distribution



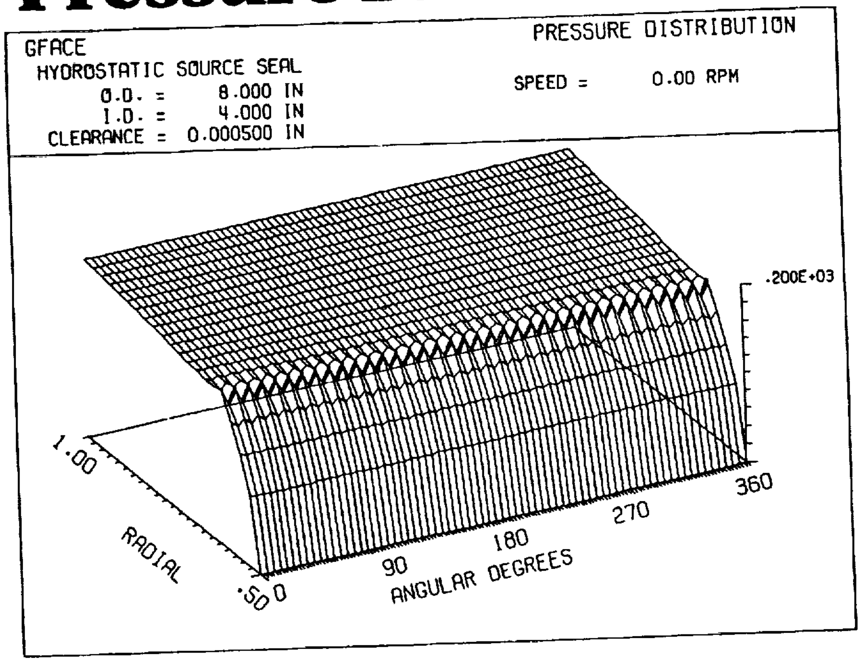
Hydrostatic Recess Seal Pressure Distribution



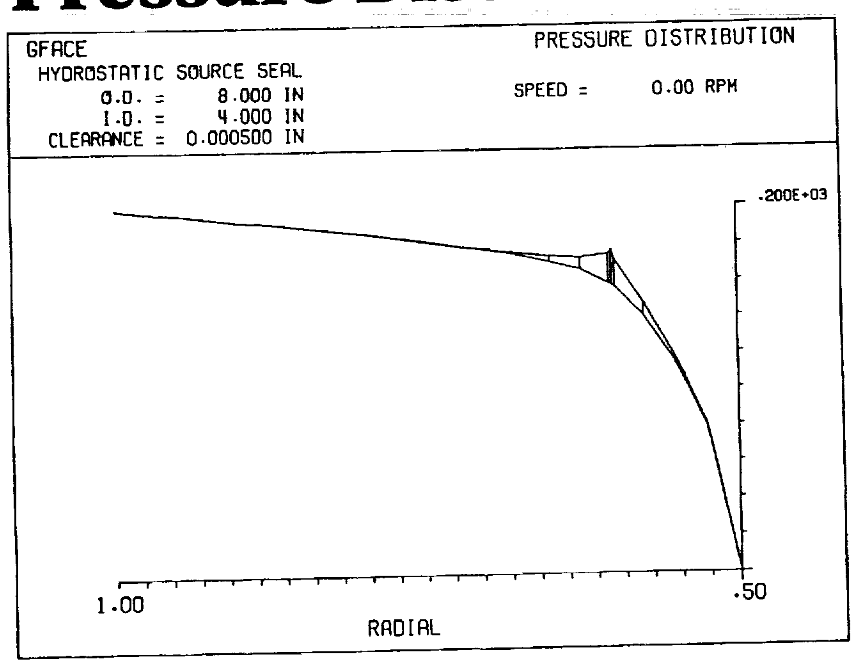
Hydrostatic Recess Seal Pressure Distribution



Hydrostatic Source Seal Pressure Distribution



Hydrostatic Source Seal Pressure Distribution



Tilted Slider Comparison

Table 6-1
Comparisons of GFACE with Etsion and Fleming
Load Capacity

Λ	ε	ζ degrees	N rpm	W' GFACE	W' Etsion & Fleming	$\Delta\%$
1	2.5	.0143	133.69	0.00476	0.0047	1.27
10	2.5	.0143	1,336.9	0.0466	0.0460	1.30
25	3.0	.0172	3,342.25	0.1086	0.1080	0.56
50	3.5	.0201	6,684.5	0.1897	0.1850	2.5
100	4.5	.0258	13,369	0.3014	0.2950	2.17

Etsion I, D. P. Fleming, *An Accurate Solution of the Gas Lubricated Flat Sector Thrust Bearing*, Trans. ASME, J. Lubr. Technology, 99:, 82-88

Tilted Slider Power Loss

Table 6-2
Comparison of GFACE with Etsion and Fleming
Power Loss

Λ	ε	PLC GFACE	PLC Etsion
1	2.5	49.4	12
10	2.5	12.86	12
25	3.0	12.987	13
50	3.5	14.193	15
100	4.5	16.15	17

$PLC = \dfrac{F}{W\omega h_2}$ *where:*

F = *Power Loss, in - lbs / s*

Etsion I, D. P. Fleming, *An Accurate Solution of the Gas Lubricated Flat Sector Thrust Bearing*, Trans. ASME, J. Lubr. Technology, 99:, 82-88

Rayleigh Step References

- Ausman, J. S. ***An Approximate Analytical Solution for Self-Acting Gas Lubrication of Stepped Sector thrust Bearings***, ASLE Transactions 4: 304-314

- Gross, W. A., et. al ***Fluid-Film Lubrication***, John Wiley & Sons, copyright 1980

GFACE Comparison with Ausman

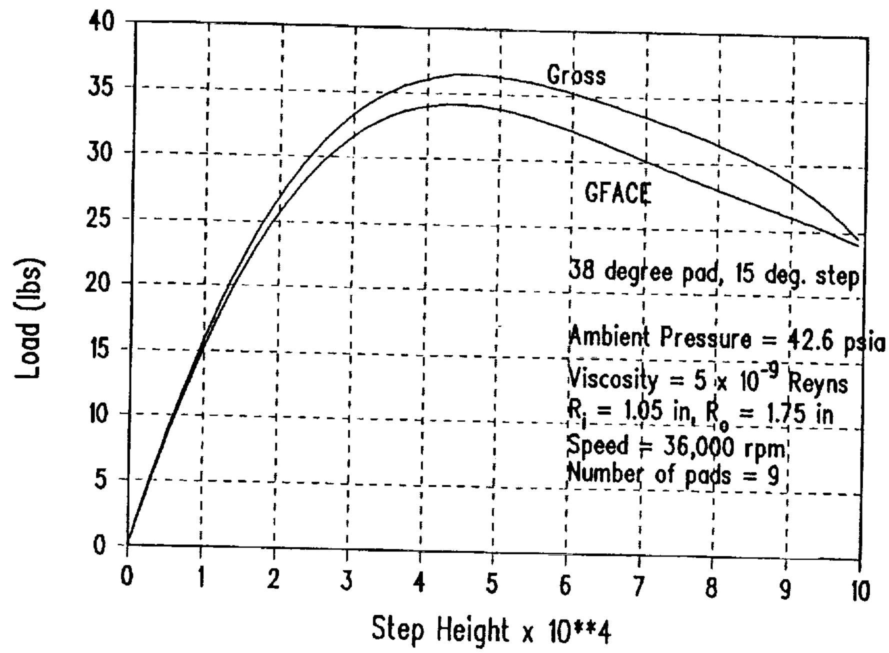
Table 6-3
GFACE Comparison with Ausman
Rayleigh-step Pad

Λ	n	W	W' GFACE	W' Ausman	Δ %
10	8	0.7539	0.0456	0.046	-.87
20	7	1.821	0.0957	0.103	-7
40	7	3.701	0.1946	0.219	-11
80	6	7.766	0.3479	0.397	-12
160	6	11.71	0.5246	0.572	-8

$\Lambda = \frac{6\mu\omega r_2^2}{P_a h_2^2}$; n = *number of pads*, $\frac{r_1}{r_2} = 0.5$

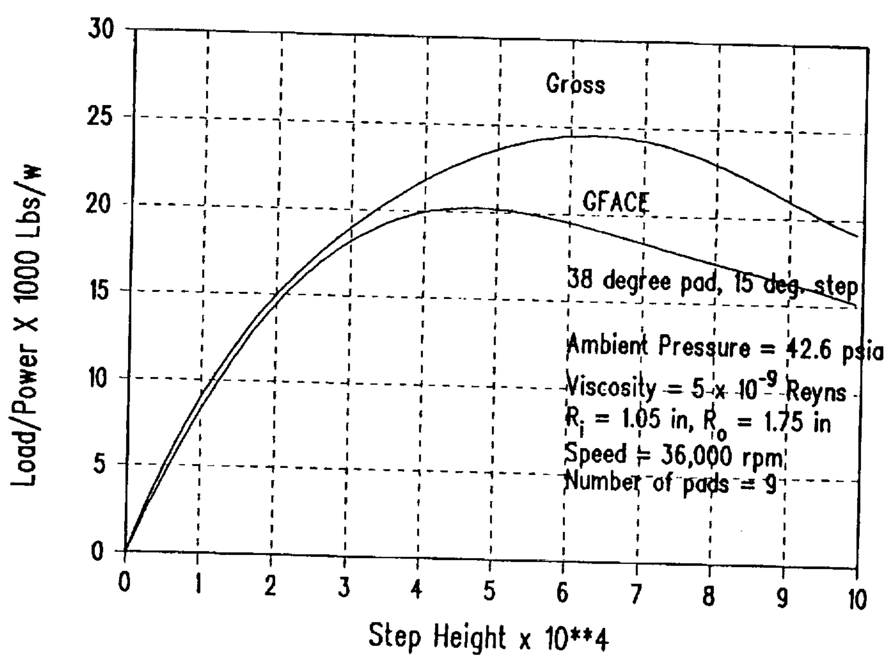
Load vs. Step height

Step Validation, Gross



Load/Power vs. Step Height

Step Validation, Gross



Automatic and Manual Stiffness Comparison

Table 6-5
Stiffness Comparisons Between Automatic and Manual Computed Values
Rayleigh-step Pad
$\delta z = 0.0001$ in, $\delta\alpha = 0.0001$ deg., $\delta\beta = 0.0001$ deg

K_{zz}	$K_{\alpha z}$	$K_{\beta z}$
34,570	27,930	-48,980
33,000	26,700	-46,700
$K_{z\alpha}$	$K_{\alpha\alpha}$	$K_{\beta\alpha}$
39,900	31,750	-57,150
40,107	34,377	-57296
$K_{z\beta}$	$K_{\alpha\beta}$	$K_{\beta\beta}$
-44,200	-35,840	62,710
-45,836	-34,337	63,025

Hydrostatic Flow Comparisons

Calculated Flow	Computer Flow
$f = 386.4\, A_o\, C_D\, G_1\, P_s \left\{ \left(\frac{P_r}{P_s}\right)^{\frac{2}{\gamma}} \left[1 - \left(\frac{P_r}{P_s}\right)^{\frac{\gamma-1}{\gamma}}\right]\right\}^{\frac{1}{2}}$ $A_o = \text{orifice area} = \frac{\pi d_o^2}{4} = \frac{\pi 0.010^2}{4} = 7.854 \times 10^{-5}$ C_D = *Coefficient of Discharge* = 0.9 $\frac{P_r}{P_s} = \frac{\text{recess pressure}}{\text{supply pressure}} = \frac{131 + 14.7}{200 + 14.7} = 0.678621$ $G_1 = \sqrt{\frac{2\gamma}{G_c \Theta (\gamma - 1)}}$ *where* γ = *ratio of specific heats* = 1.4 G_c = *gas constant* = 246,900 $\frac{in^2}{s^2 - {}^{\circ}R}$ Θ = *absolute temperature* = $1460^{\circ}R$ $f = 386.4 x 7.854 x 10^{-5} x 0.9 x 1.3935 x 10^{-4} x 214.7$ $x \left\{ (0.678621)^{\frac{2}{1.4}} \left[1 - (0.678621)^{\frac{0.4}{1.4}}\right]\right\}^{\frac{1}{2}} = 2.006 x 10^{-4}\ \frac{lbs}{s}$	2.0022 x 10^{-4} lb/s